Cloud resolving modeling: the GCSS story and beyond

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1. Creation of GCSS

   (a) First documents: Browning et al. (1993).

   (b) "The focus of GCSS is on cloud systems spanning the mesoscale rather than on individual clouds. Observations from field programs will be used to develop and validate the cloud-resolving models, which in turn will be used as test-beds to develop the parameterizations for the large-scale models."

   (c) Four different cloud system types were chosen to study: boundary layer, deep convective precipitating, frontal, and cirrus.

   (d) Working groups were formed for all of the cloud system types. The WGs organized model intercomparison studies and meetings to present results of the intercomparisons.

2. ARM Data and Single-Column Modeling

   (a) The ARM program was established to improve the understanding of atmospheric radiation and its interaction with clouds and cloud processes. The goal was to make measurements of atmospheric radiation and the atmospheric properties that affect it at five (later reduced to three) fixed sites for up to 10 years, and to use the measurements to test cloud and radiation parameterizations of varying complexity.

   (b) Randall et al. (1996) proposed to use field data such as that collected by ARM together with single-column models (SCMs) and cloud ensemble models to test physical parameterizatins used or to be used in GCMs.

   (c) Winter 1994 Single Column Model IOP led by David Randall.
   Starting with this IOP, seasonal SCM IOPs were conducted at the Southern Great Plains to enhance the frequency of observations for SCM uses, particularly vertical soundings of temperature, water vapor, and winds. The SCM IOPs are conducted for a period of 21 days. During that time, radiosondes are launched at the Central Facility and the four boundary facilities eight times per day,

seven days per week. The data are required for quantifying boundary forcing and column response.

(d) The constrained variational analysis method was developed by Zhang and Lin (1997) for deriving large-scale vertical velocity and advective tendencies from sounding measurements. It is used to process atmospheric soundings of winds, temperature, and water vapor mixing ratio over a network of a small number of stations. Given the inevitable uncertainties in the original data, the basic idea in this objective analysis approach is to adjust these atmospheric state variables by the smallest possible amount to conserve column-integrated mass, moisture, static energy, and momentum. The analysis products include both the large-scale forcing terms and the evaluation fields, which can be used for driving SCMs/CRMs and evaluating model simulations. The first analysis data set produced for ARM was based on the Summer 1995 SCM IOP. This was followed by ones for the Spring, Summer, and Fall 1997 SCM IOPs.

(e) ARSCL: Active Remote Sensing of CLouds.
This value-added product combines the data from millimeter cloud radars, laser ceilometers, microwave radiometers, and micropulse lidars to produce a time series of vertical distributions of cloud hydrometeors over the ARM sites. This product first became available for the SGP site in November 1996, and a stable version for the general mode became available on April 1, 1997.

3. Continental deep convection brings GCSS and ARM together

(a) The inaugural model intercomparison meeting of Working Group 4 (Precipitating Convective Cloud Systems) was Evaluation and Intercomparison of GCSS Cloud-Resolving Models using TOGA COARE Observations held 2123 October 1996 in Annapolis, Maryland (Moncrieff et al. 1997). To complement the model intercomparison and evaluation work, the GCSS Working Group 4 has cohosted two other scientific meetings. The WCRP Workshop on Cloud Microphysics Parameterizations in Global Atmospheric Circulation Models, held 2325 May 1995, in Kananaskis, Alberta, Canada. The European Centre for Medium-Range Weather Forecasts (ECMWF) Workshop on New Insights and Approaches to Convective Parameterization, was held 47 November 1996.

(b) Moncrieff et al. (1997) referred to Randall et al.'s (1996) proposed method of using SCMs and CRMs to test and develop physically based parameterizations.

(c) The main actions and recommendations from the GCSS-6 meeting in Boulder, Colorado, USA (1-5 December 1997) included this action item for Working Group 4:

> Investigate the possibility of developing a continental case study built on data from the USA, Department of Energy, Atmospheric Ra-

diation Measurement (ARM) Program. Include the possible options for such a case in the Working Group-4 report at the 1998 GCSS meeting.

(d) The GEWEX Cloud System Study (GCSS) Science Panel Seventh Session (Kauai, Hawaii, USA, 1-4 December 1998 recommended that

> WG-4 should proceed with a continental deep convection case drawn from data taken at the ARM Southern Great Plains experimental site during July 1997. Specialized instrumentation including a millimeter cloud radar (MMCR) and an extensive array of other meteorological instruments were operational at that time. This case will be done in collaboration with the ARM Single Column Modelling Group as a means of involving more of the SCM community to participate in the process and to gain support of the ARM Data and Science Integration Team (DIST) in the provision of forcing data and the compilation of results submitted by the modelling groups.

4. GCSS and ARM: Confronting Models With Data

(a) WG-4 Case 3: Summer 1997 ARM SCM IOP (procedure document available July 1999)

(b) WG-1 2000 ARM Continental cumulus with diurnal cycle:
Continental shallow cumulus boundary layer diurnal cycle (ARM Oklahoma site).
Jan. 2000, Boulder, Colorado, USA
Case coordinator: Andy Brown, Met Office, UK
Brown et al., 2002: Large-eddy simulation of the diurnal cycle of shallow cumulus convection over land. Quart. J. Roy. Meteor. Soc., 128, 1075-1093.

(c) 22–24 October 2001, Boulder, CO, USA: Joint GCSS WG 4/ARM CPM (Cloud Parameterization and Modeling)

(d) GCSS-ARM Workshop on the Representation of Cloud Systems in Large-Scale Models, 20-24 May 2002, Kananaskis Village, Alberta, Canada

(e) GEWEX SSG Jan 2003 report on GCSS: The next MIP for WG 2 (Cirrus cloud systems) will be based on cirrus from Hurricane Nora (26 Sept 1997) as observed at the ARM Southern Great Plains (SGP) site. The current MIP for WG 3 (Extratropical layer cloud systems) is based on the March 2000 IOP at the ARM SGP. In addition to ground-based and satellite remote-sensing measurements of clouds, there were many made in situ from aircraft.

(f) 27-30 Oct 2003: GCSS WGs 1, 3, 4 held workshops in Broomfield, CO, in conjunction with the DOE ARM Cloud Parameterization and Modeling WG and Cloud Property WG. The GCSS Science Steering Group also met.

(g) Randall, D.A., and 10 co-authors, 2003: Confronting Models With Data: The GEWEX Cloud Systems Study. The highlight is a new strategy that includes a more active role for the large-scale modeling community, and an explicit recognition of the importance of data integration.

(h) Joint ARM/GCSS WG 5 (Polar Clouds) Model Intercomparison based on case studies developed from the Mixed-Phase Arctic Cloud Experiment (MPACE) during Fall 2004 over the northern Alaska coastline. Initial results were presented at the ARM Cloud Parameterization and Modeling Working Group meeting in San Francisco, CA (Oct 30-31, 2006).

(i) 2006: TWP-ICE

(j) Other joint GCSS and ARM projects?

(k) Randall was Chair of GCSS from 1997 to 2000

(l) Krueger was Chair of GCSS WG 4 from 1997 to 2000

(m) Krueger was Chair of GCSS from 2001 to 2004

5. Summary

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